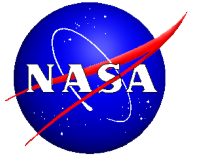


Suomi NPP CERES Instrument Status and Data Product Development



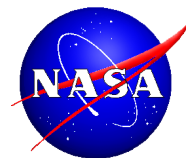
Paul Stackhouse with inputs from Norman Loeb (PI), Jonathan Gleason, Kory Priestley,
Susan Thomas, David Doelling and the CERES Science Team
NASA LaRC, June 21, 2012

Overview



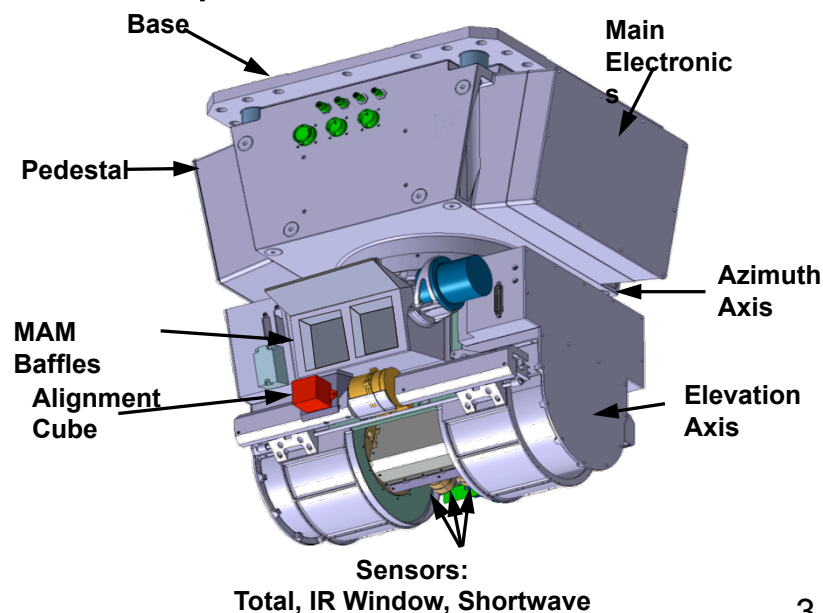
- CERES Background and Overview
- Current Instrument Status
- CERES Data Products
- Data Release Schedule
- CERES Subsetting and Data Distribution
- Example Usage

Clouds and Earth's Radiant Energy System (CERES) Overview

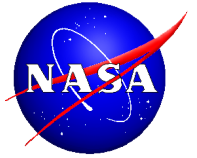


- CERES Objective: To produce a long-term record of radiation budget from the top-of-atmosphere (TOA), within atmosphere and at the surface with consistent cloud and aerosol properties at climate accuracy
- The CERES Instrument is a 3-channel scanning radiometer designed to measure Earth's reflected solar and emitted thermal radiation as fluxes at the top of the atmosphere.
- Currently CERES fuses data from 11 instruments on 7 spacecraft, all integrated to obtain climate accuracy in the top and bottom radiative fluxes.

Orbits	705 km altitude, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (PM-1), sun-synchronous, near-polar; 350 km altitude, 35° inclination (TRMM)
Spectral Channels	Solar Reflected Radiation (Shortwave): 0.3 - 5.0 μm Window: 8 - 12 μm Total: 0.3 to > 100 μm
Swath Dimensions	Limb to limb
Spatial Resolution	20 km at nadir (10 km for TRMM)
Mass	45 kg
Size	60 x 60 x 70 cm (deployed)
Design Life	6 years



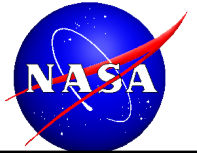
CERES and ERB CARS



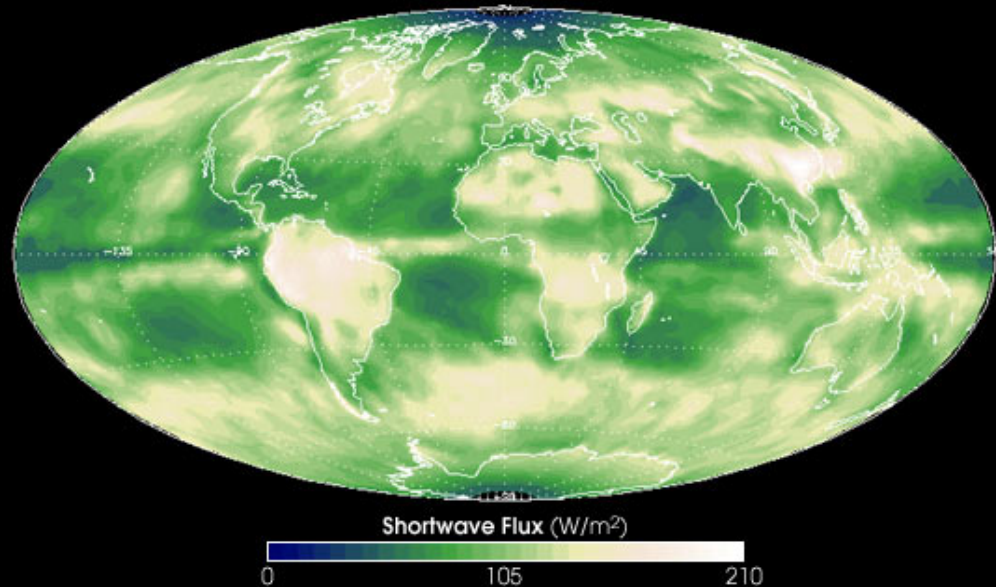
- ERB CARS is an element of the NPP Science Data Segment, and receives NPP data from the Land Product Evaluation and Test Element (PEATE) at GSFC.
- ERB CARS objective: to extend the CERES climate record using data from the FM5 instrument on NPP
- CERES Flight Model 5 is the 6th CERES instrument to fly (PFM – TRMM, FM1-2 Terra, FM3-4 Aqua)



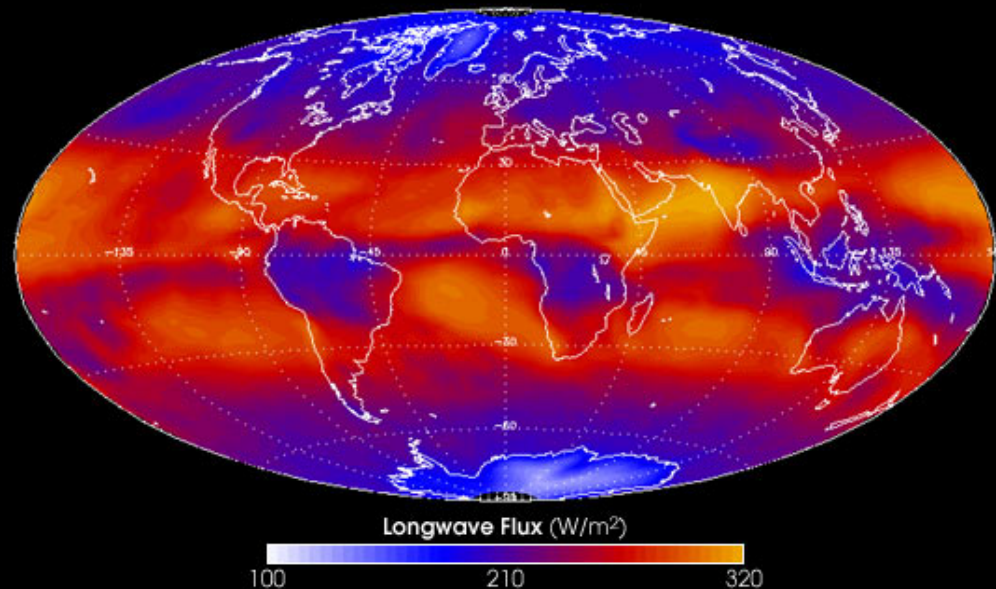
Primary CERES Climate Data Records

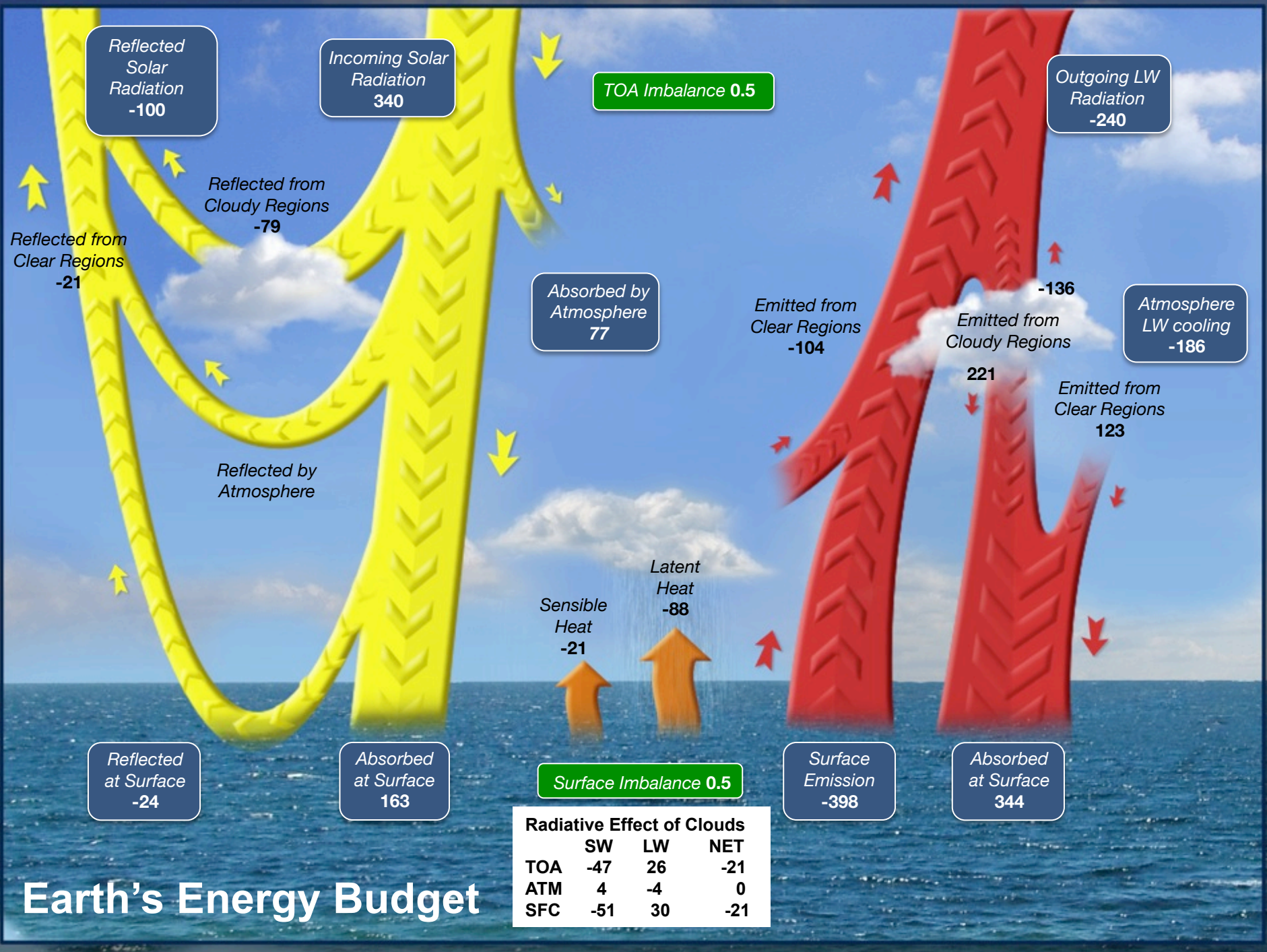


**Reflected
Solar Energy**



**Emitted
Thermal Energy**

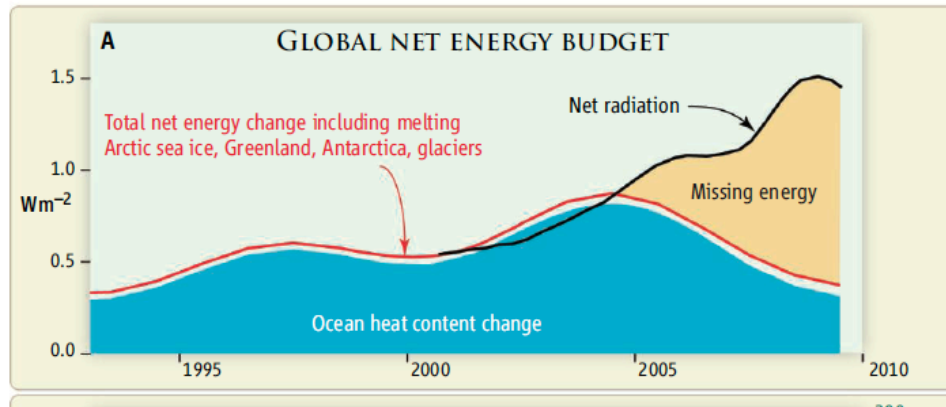




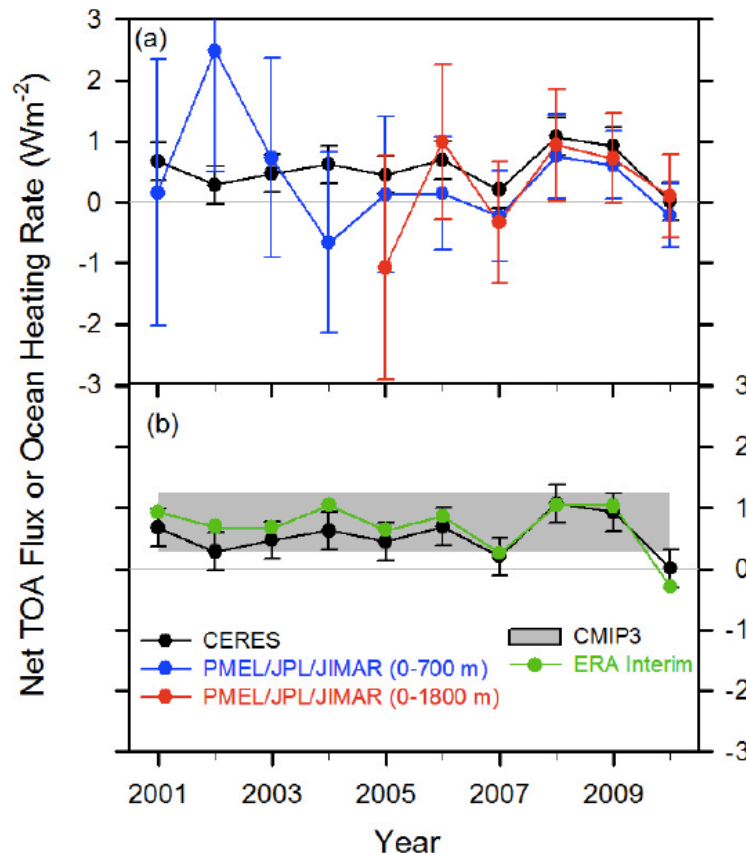
Radiative Effect of Clouds			
	SW	LW	NET
TOA	-47	26	-21
ATM	4	-4	0
SFC	-51	30	-21

Earth's Energy Budget

Comparison of CERES net TOA flux and Upper Ocean Heating Rates



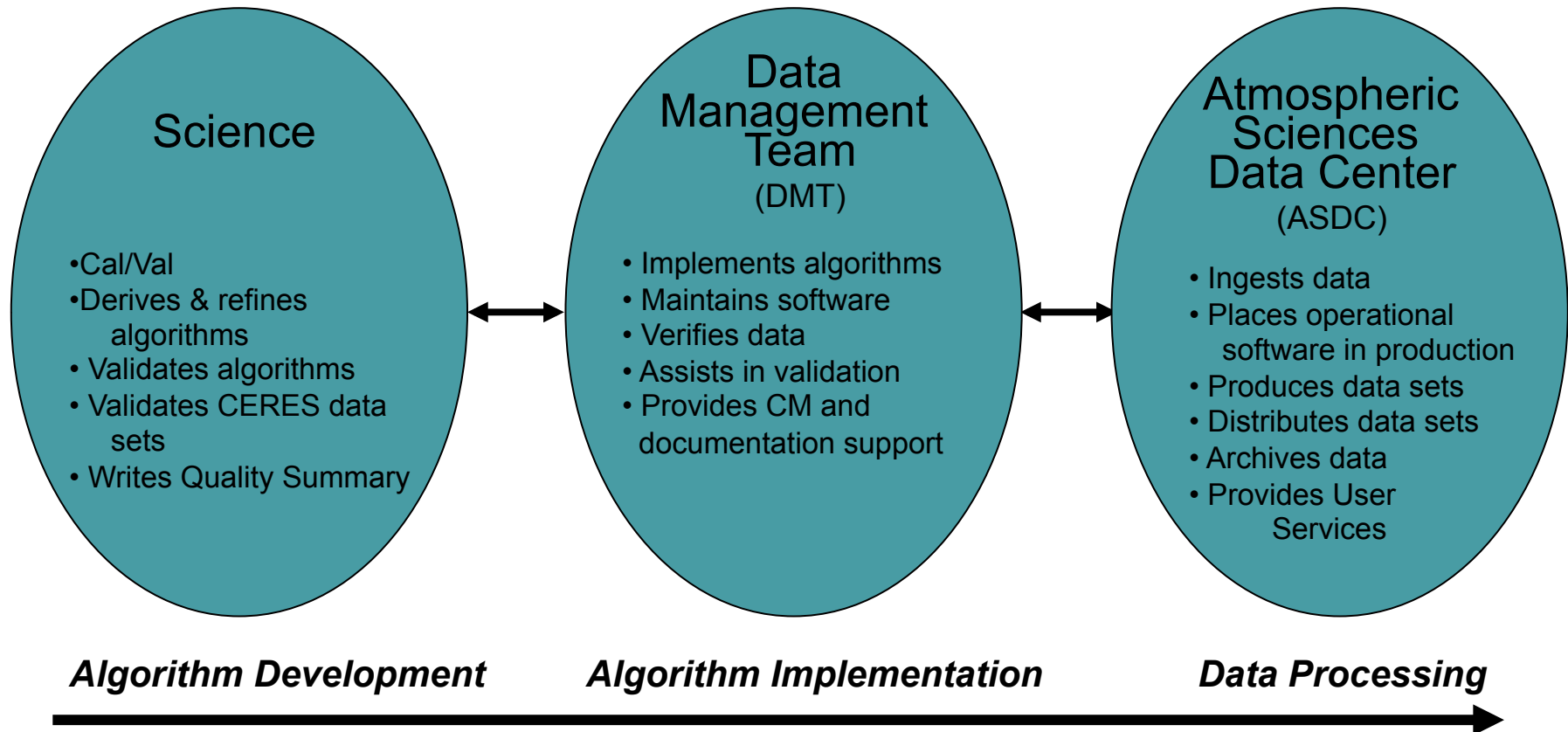
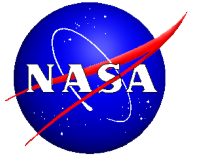
- Apparent inconsistencies after 2004 between short-term variations in ocean heating rate from in situ ocean heat content data and net TOA flux from CERES cast doubt on our ability to account for flows of energy in the climate system.
- Lack of closure has given rise to the idea of “missing energy” in the climate system. (Trenberth & Fasullo, Science 2010)



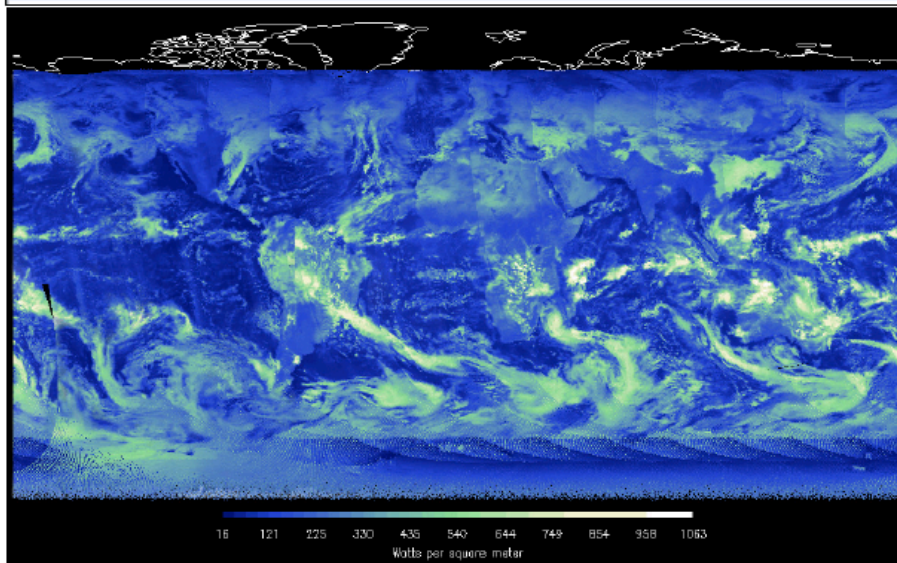
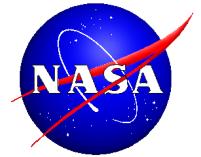
- Reduction in ocean heating rate claimed in TF10 is not statistically robust and occurs during the XBT to Argo transition, a period of large uncertainty.
- During the past decade Earth has been accumulating energy at the rate $0.51 \pm 0.43 \text{ Wm}^{-2}$.
- Combined use of CERES and in-situ ocean heating rate provides accurate observations of Earth's planetary imbalance over a range of spatial and temporal scales.

(Loeb et al., Nature Geoscience 2011)

CERES Organization

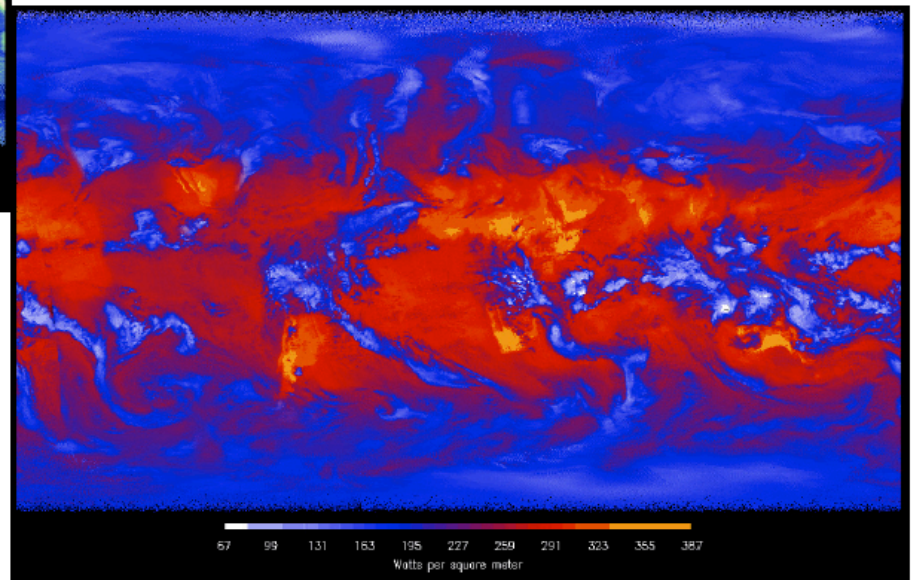


First CERES FM5 Images

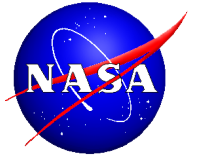


SHORTWAVE FLUX

LONGWAVE FLUX



FM-5 History to Date

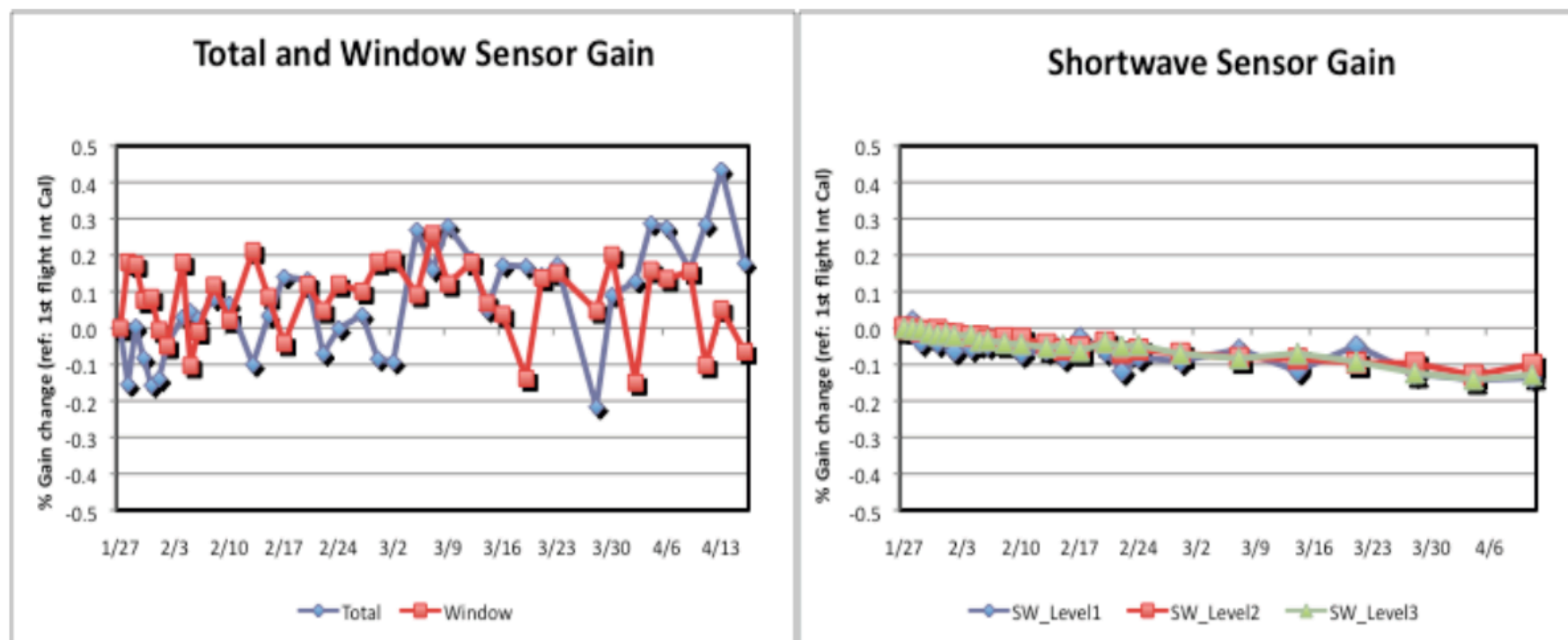


NPP Spacecraft Launch – October 28, 2011
CERES Power On – November 9, 2011
Covers Closed Instrument Ops – Nov 9, 2011 – Jan 25, 2012
Calibration using ICM Sources – Nov 10, 2011 – Feb 8, 2012
CERES Main and MAM Cover Open – January 26, 2012
MAM Conditioning Operation – Jan 28 – 29, 2012 (22 orbits)
CERES Solar MAM Calibration – January 28, 2012
Spacecraft YAW Maneuver – Feb 17 – 18, 2012
Spacecraft Pitch Back Maneuver – February 20, 2012
NPP LEO&A Period End – March 7, 2012

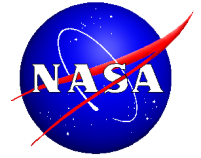
FM-5 Gain Performance



The performance of CERES sensors are within the expected range - $\pm 0.5\%$



CERES FM-5 Validation



Comparison of FM5 LW and SW Flux Average (Feb & March 2012) with CERES FM1- FM3 [Ed1-CV]

	FM5 Wm-2	FM1 Wm-2	FM5-FM1 (%)	FM2 Wm-2	FM5-FM2 (%)	FM3 Wm-2	FM5-FM3 (%)
LW	236.01	237.73	-0.72	240.5	-1.87	237.32	-0.55
SW	100.59	97.185	3.5	96.22	4.55	97.23	3.46

Tropical Mean: Average of All-sky tropical ocean(20°N-20°S)
Longwave (night) radiance measurement

FM5 LW (night) Radiance average for Feb & March 2012
comparison with CERES FM1- FM3

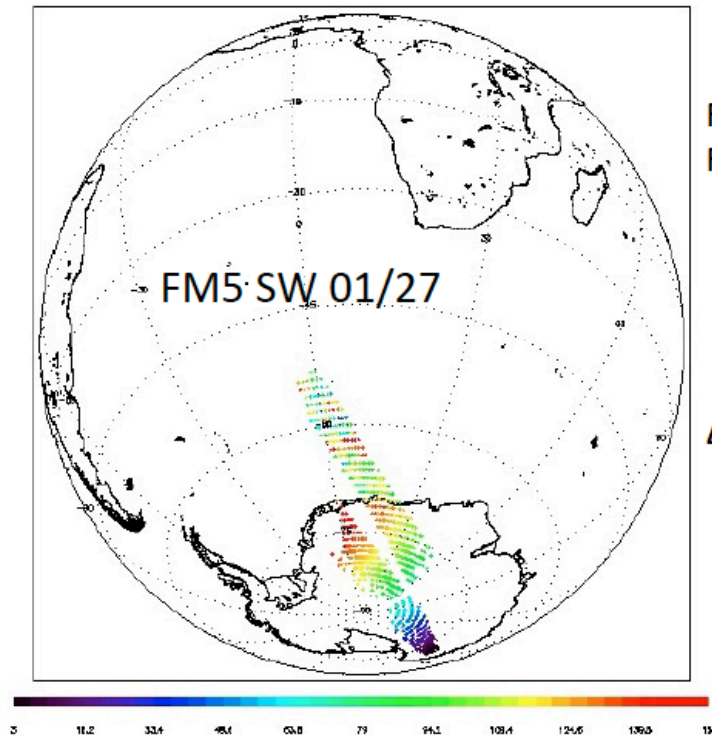
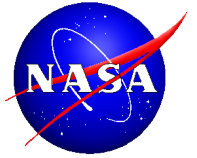
	FM5 Wm-2sr-1	FM1 Wm-2sr-1	FM5-FM1 (%)	FM2 Wm-2sr-1	FM5-FM2 (%)	FM3 Wm-2sr-1	FM5-FM3 (%)
LW-night (Ed1-CV)	87.606	88.421	-0.92	88.114	-0.58	88.432	-0.93
LW-night (Ed3-Gain)	87.606	87.894	-0.33	87.454	0.17	87.93	-0.37

CERES FM-5 Validation



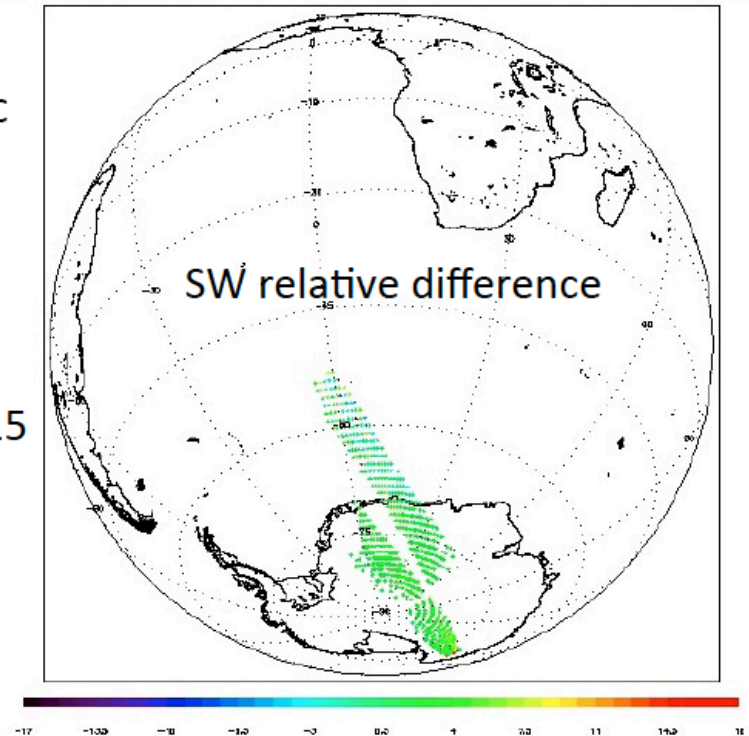
- NPP and Aqua Simultaneous Observation Opportunities occur every 64 hours and last ~20minutes with views < 15 sec apart.
- Comparison based on gridded $1^{\circ} \times 1^{\circ}$ averages with relative VZA < 5 deg and RAZ < 1 deg.
- 34 orbital crossing opportunities (8 in Tropics, 11 in Polar regions, 15 mid-latitudes) during Feb – April, 2012.

CERES FM-5 Validation



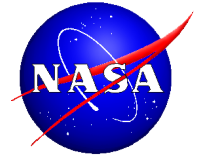
FM5 – Baseline1-QC
FM3 – Ed1-CV

$$\Delta SW \approx 3\% \pm 0.15$$



- (1) FM5 reads higher in SW, lower in LW
- (2) Differences on par with changes from Ed1 to Ed3 for FM3

Suomi NPP CERES FM-5 Instrument Conclusions



- FM-5 continues to operate nominally.
- No instrument performance anomalies to date.
- The intensive cal/val campaign has completed for CERES FM-5.
- Assessment of the on-orbit spatial, spectral, temporal, and radiometric performance is nearing completion.
 - Initial results demonstrate flight performance is within expected bounds.
- Final delivery of updated calibration coefficients by 7/1
- Long-Term monitoring period has begun.
- Special operations to support intercomparison of CERES instruments on NPP, Terra and Aqua have commenced.

CERES Data Processing Flow



**CERES Level-0
Measurements**

Ephemeris &
Attitude

Geolocate
And
Calibrate

**Bidirectional
Scans
(BDS)**

Snow & Ice
Coverage

Determine
TOA Fluxes

**ERBE
Footprints
(ES8)**

Gridding and
Time-Space
Average

**ERBE
Hourly, Daily
Monthly
(ES4/ES4G/ES9)**

**ERBE-Like
Stream
(ERBE Algorithm)**

Bidirectional Scans (BDS – level 1)
and ERBE-like Stream

ES8 (level 2)
ES4 (level 3)
ES9 (level 4)

Data Product Level

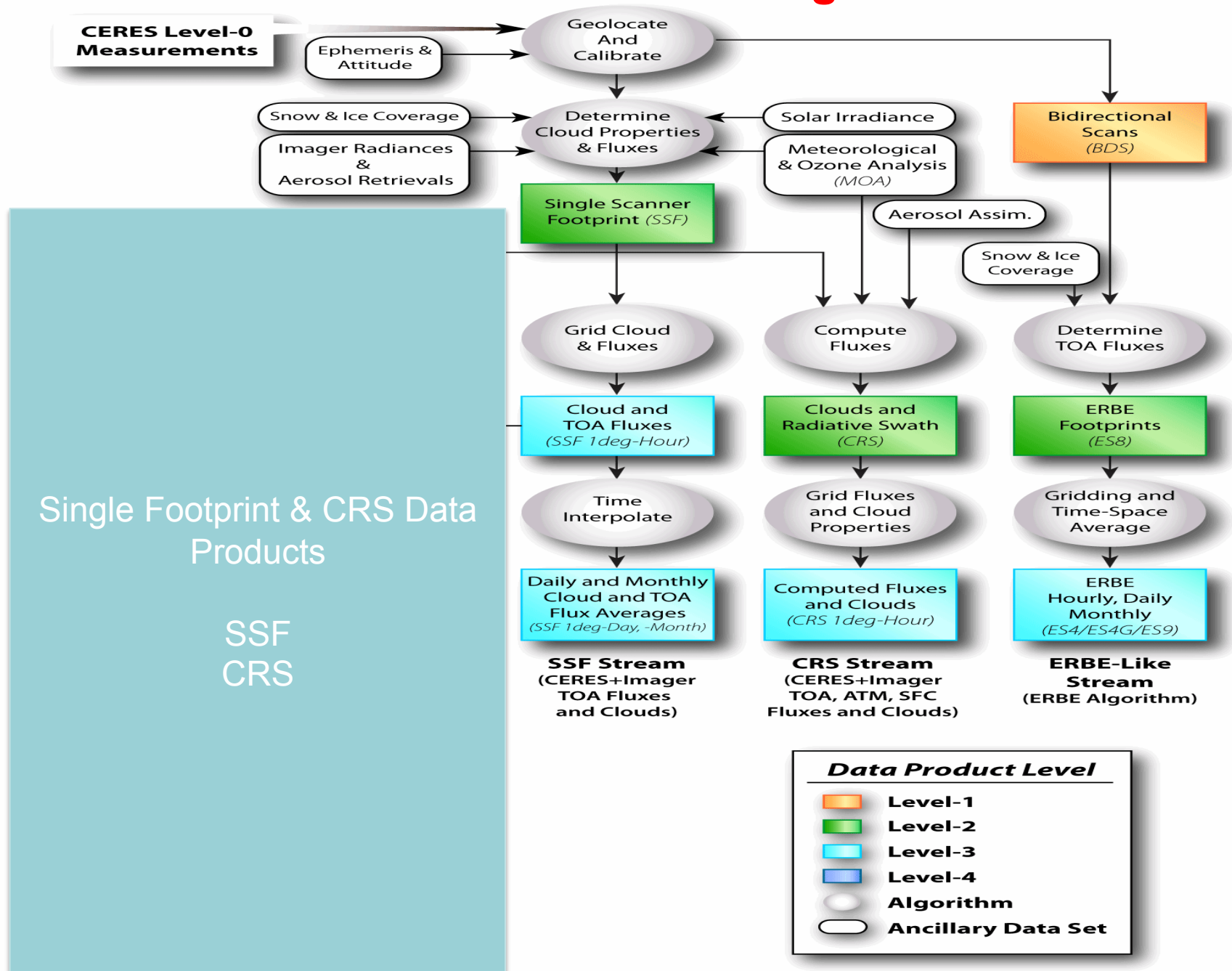
-  **Level-1**
-  **Level-2**
-  **Level-3**
-  **Level-4**
-  **Algorithm**
-  **Ancillary Data Set**

CERES Data Products (ERBE-like)

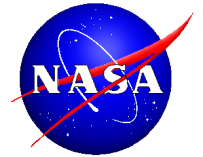


Product Stream	Product Name	Level	Description
Instrument	BDS	1B	CERES geolocated and calibrated TOA filtered SW, TOT, and WN radiances for views of space, internal calibration, solar calibration and Earth.
ERBE-like	ES8	2	CERES observed TOA fluxes using original ERBE algorithms. For comparisons between CERES & ERBE data. ES8 hour products footprint resolution. ES9 instantaneous gridded and ES4 gridded temporal averaged
	ES9	3	
	ES4	3	

CERES Data Processing Flow

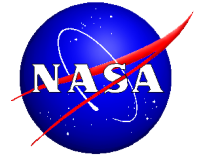


CERES Data Products (SSF)



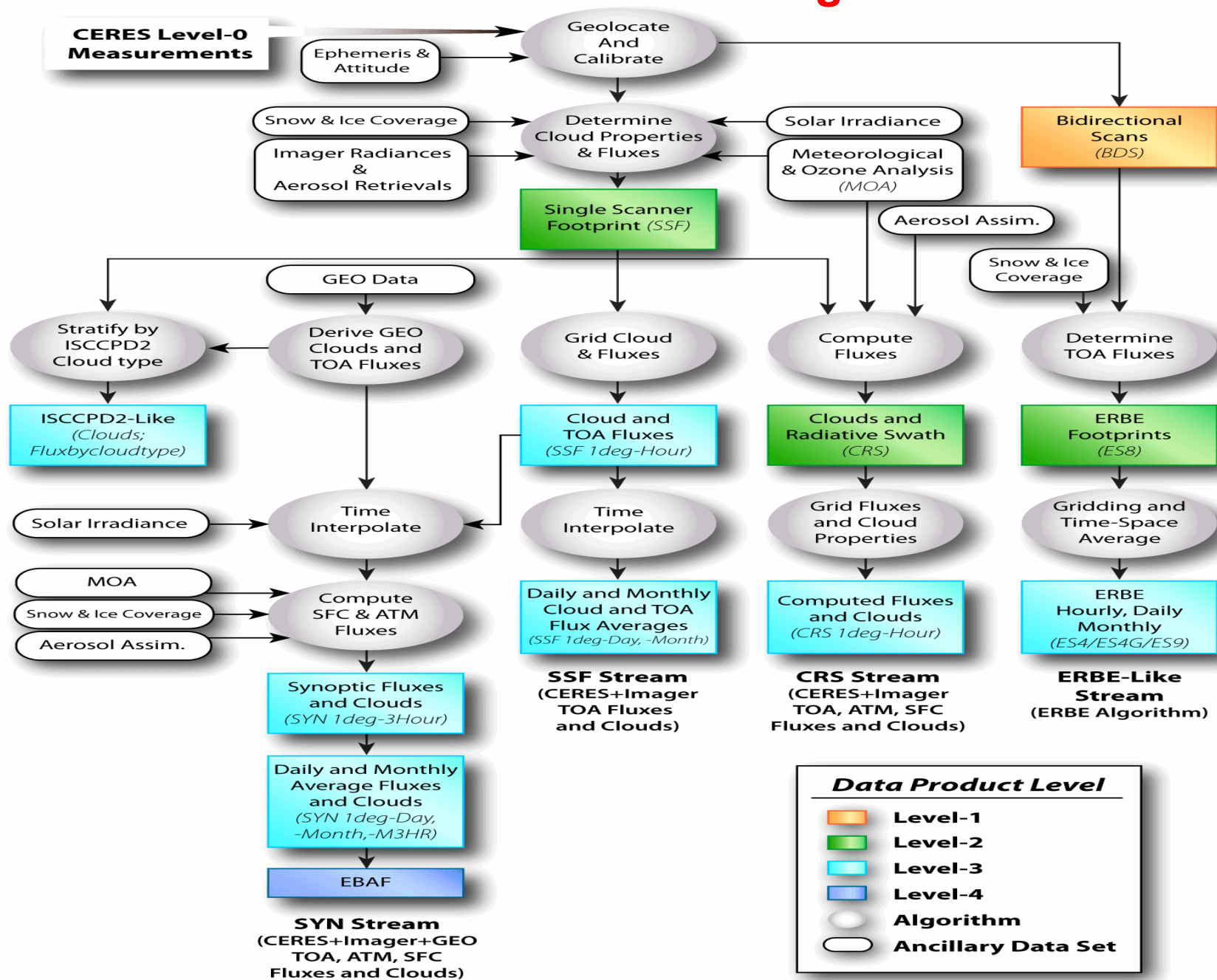
Product Stream	Product Name	Level	Description
SSF (Single Scanner Footprint)	SSF	2	CERES observed TOA fluxes, parameterized surface fluxes, and imager-derived cloud and aerosol properties.
	SSF1deg-Hour	3	Instantaneous TOA and parameterized surface fluxes and cloud/aerosol properties averaged onto a regular 1° equal-area grid and sorted by local hour.
	SSF1deg-Day	3	CERES observed, temporally interpolated, daily, 1° equal-area, zonal and global averages of TOA fluxes and imager-derived clouds and aerosol properties.
	SSF1deg-Month	3	Same as SSF1deg-Day but averaged over an entire Month

Data Products (CRS)

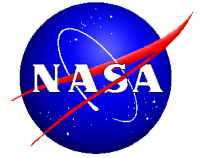


Product Stream	Product Name	Level	Description
CRS (Cloud Radiative Swath)	CRS	2	Computed flux from 4-stream radiative transfer model and cloud/aerosol properties
	CRS1deg-Hour	3	Instantaneous computed fluxes and cloud/aerosol properties averaged onto a 1° equal-area grid and sorted by GMT hour.

CERES Data Processing Flow

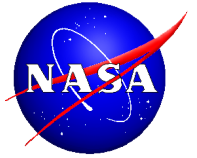


CERES Data Products



Product Stream	Product Name	Level	Description
SYN (Synoptic)	SYN1deg-3Hour	3	GEO enhanced CERES temporally interpolated 3-hourly average 1° equal-area TOA fluxes, imager/GEO cloud and imager aerosol properties.
	SSF1deg-Day	3	Same as SYN1deg-3Hour but for daily averages.
	SYN1deg-Month	3	Same as SYN1deg-3Hour but for monthly averages
	SYN1deg-M3Hour	3	Same as SYN1deg-3Hour but for hourly averages.
	EBAF	4	1° equal-area monthly mean CERES TOA fluxes optimally constrained by the net TOA flux imbalance derived from ocean heat content data.

Tentative Data Release Milestones



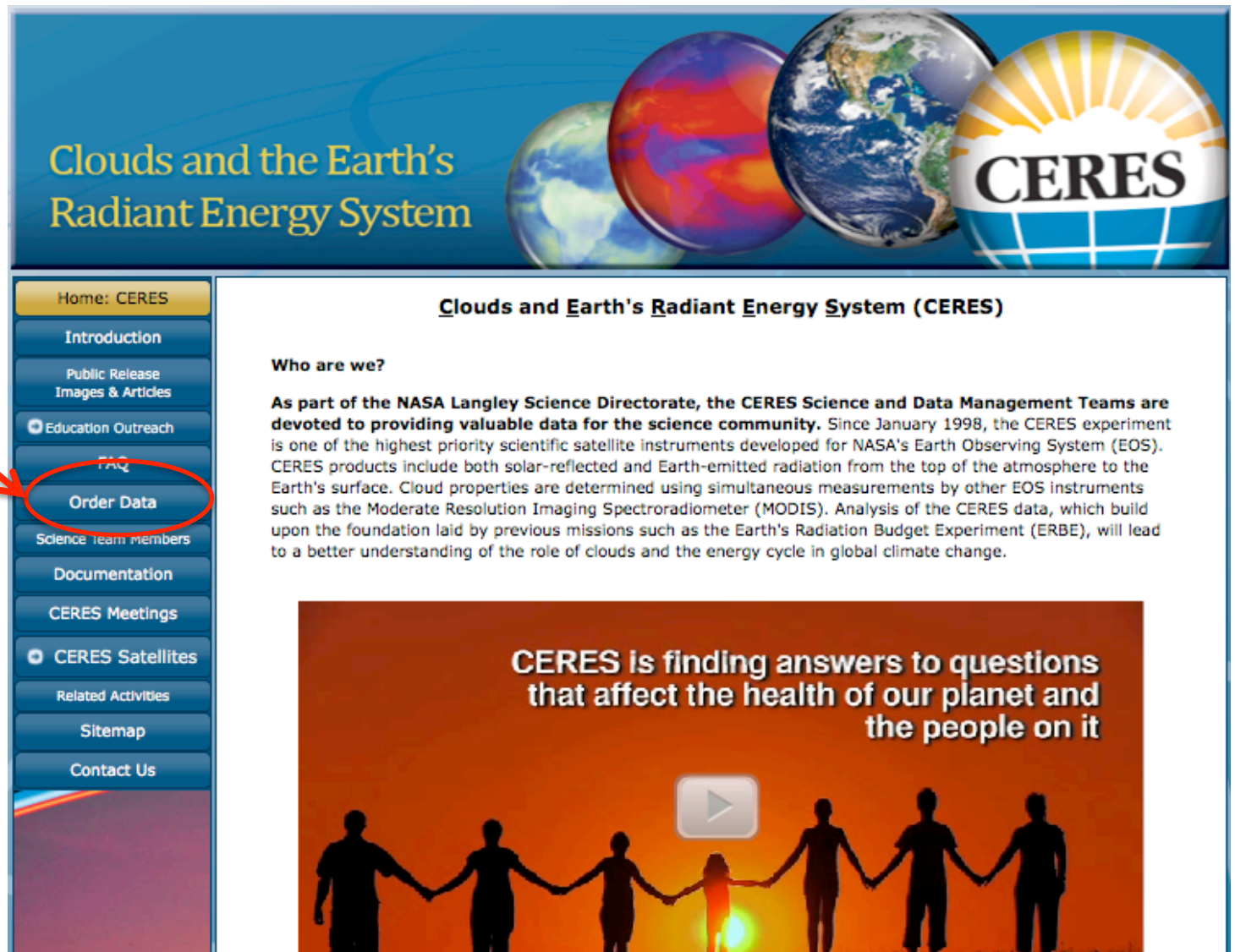
- Covers open + 228 days (~ Sept, 2012) public release Edition1-CV BDS, ES8, ES9 & ES4 products
- Covers open + 452 days (~ April 2013) public release reprocessed Edition 2 BDS, ES8, ES9 & ES4
- Covers open + 530 days (~ June 2013) public release SSF (pending VIIRS availability)
- Covers open + 659 (~ Nov 2013) days public release SSF1deg-Hour with other gridded level 3 and 4 products to follow

CERES Data Subsetting Tool



<http://ceres.larc.nasa.gov>

Link to
Data
access
and
subsetting



The screenshot shows the CERES Data Subsetting Tool website. The header features the title "Clouds and the Earth's Radiant Energy System" and a banner with four globes, the last of which is labeled "CERES". A left sidebar contains a navigation menu with the following items: "Home: CERES", "Introduction", "Public Release Images & Articles", "Education Outreach", "FAQ", "Order Data" (highlighted with a red circle and an arrow from the text "Link to Data access and subsetting"), "Science Team members", "Documentation", "CERES Meetings", "CERES Satellites", "Related Activities", "Sitemap", and "Contact Us". The main content area is titled "Clouds and Earth's Radiant Energy System (CERES)" and includes a section "Who are we?" with a paragraph about the mission. Below this is a video player with the text "CERES is finding answers to questions that affect the health of our planet and the people on it" and a play button icon over a silhouette of people holding hands.

Clouds and the Earth's Radiant Energy System

Home: CERES

- Introduction
- Public Release Images & Articles
- Education Outreach
- FAQ
- Order Data**
- Science Team members
- Documentation
- CERES Meetings
- CERES Satellites
- Related Activities
- Sitemap
- Contact Us

Clouds and Earth's Radiant Energy System (CERES)

Who are we?

As part of the NASA Langley Science Directorate, the CERES Science and Data Management Teams are devoted to providing valuable data for the science community. Since January 1998, the CERES experiment is one of the highest priority scientific satellite instruments developed for NASA's Earth Observing System (EOS). CERES products include both solar-reflected and Earth-emitted radiation from the top of the atmosphere to the Earth's surface. Cloud properties are determined using simultaneous measurements by other EOS instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS). Analysis of the CERES data, which build upon the foundation laid by previous missions such as the Earth's Radiation Budget Experiment (ERBE), will lead to a better understanding of the role of clouds and the energy cycle in global climate change.

CERES is finding answers to questions that affect the health of our planet and the people on it



CERES subsetter product selection page

Level 4: Spatially (regional, global, etc.) and temporally (daily, monthly, etc) averaged fluxes where the net flux has been energy balanced.

Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
EBAF-TOA	Monthly and climatological averages of TOA clear-sky (spatially complete) fluxes, all-sky fluxes, and cloud radiative effect (CRE), where the TOA net flux is constrained to the ocean heat storage . Data Quality Summary	i	i	i	Browse & Subset
EBAF-Surface	Monthly and climatological averages of computed surface clear-sky fluxes, all-sky fluxes, and cloud radiative effect (CRE), consistent with the CERES EBAF-TOA fluxes. Data Quality Summary	i	i	i	Browse & Subset

Level 3: Spatially (regional, global, etc.) and temporally (daily, monthly, etc) averaged fluxes and clouds.

Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
SYN1deg	CERES geostationary (GEO) enhanced temporally interpolated TOA fluxes, MODIS and 3-hourly GEO cloud properties, MODIS aerosols, and computed TOA, surface and in-atmospheric (profile) fluxes consistent with the observed TOA fluxes, clouds and aerosols. Data Quality Summary	i	i	i	Browse & Subset
SSF1deg	CERES constant meteorology temporally interpolated TOA fluxes, MODIS clouds and aerosols. Data Quality Summary	i	i	i	Browse & Subset
ISCCP-D2like	CERES-MODIS and GEO daytime cloud properties stratified by ISCCP cloud types and in the similar D2 format. Data Quality Summary	i	i	i	Browse & Subset

Level 2: CERES instantaneous footprint level (20km nominal) fluxes and cloud properties.

Data Product (Information & Documentation)	Description	Parameter	Resolution	Version/ Availability	Order Data
SSF	CERES observed TOA fluxes, MODIS clouds and aerosols, and parameterized surface fluxes. Terra Data Quality Summary Aqua Data Quality Summary	i	FOV*	i	Browse & Subset



[Selection Page](#) [My Orders](#)

Parameters

▼

☑ Surface Fluxes ⓘ

▶

☐ Surface CRE Fluxes ⓘ

[Click to select individual parameters](#)

	All Sky	Clear Sky
<input checked="" type="checkbox"/> Shortwave Flux Down ⓘ	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Shortwave Flux Up ⓘ	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Longwave Flux Down ⓘ	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Longwave Flux Up ⓘ	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Net Shortwave Flux ⓘ	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Net Longwave Flux ⓘ	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Net Total Flux ⓘ	<input type="checkbox"/>	<input type="checkbox"/>

Temporal Resolution

☒ Monthly Mean

☐ Climate

Spatial Resolution

☒ Regional (1° x 1° global grid)

☐ Zonal mean

☐ Global mean

90

West 0 reset 360 East

-90

South

Time Range

Available Time Range: 3/1/2000 to 2/28/2010.

From: 03 - 2000 (MM-YYYY) To: 02 - 2010 (MM-YYYY)

Email Address

guest@ceres.tool

By providing your email address you will be informed of any future revisions of your download, product, etc.

[Browse Data](#)

[Get Data](#)

[Add to Cart](#)

[Reset Selections](#)

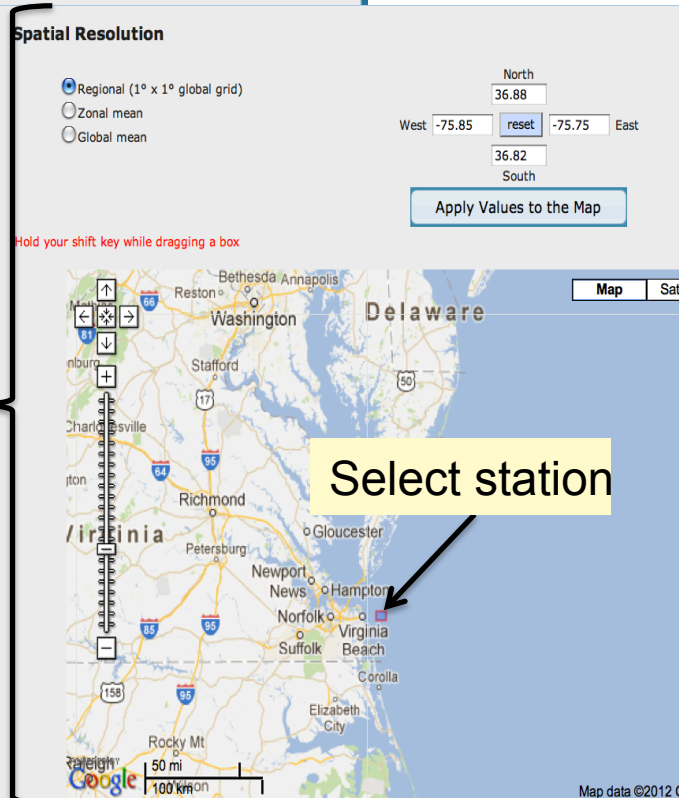
EBAF-surface parameter selection

EBAF-surface temporal selection

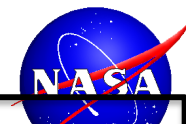
EBAF-surface spatial selection

Site can be as small as 1°by1° lat/lon or large as the globe

Select station



Site Analysis Toolbar



Save Data as ASCII File

Save Image as PNG

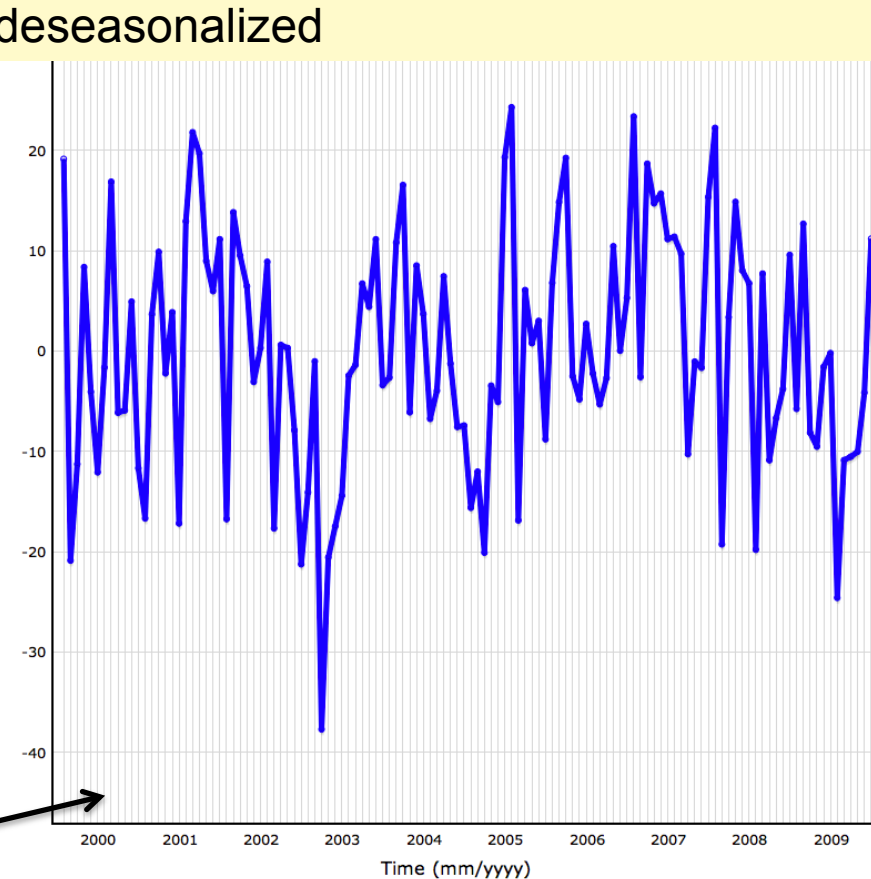
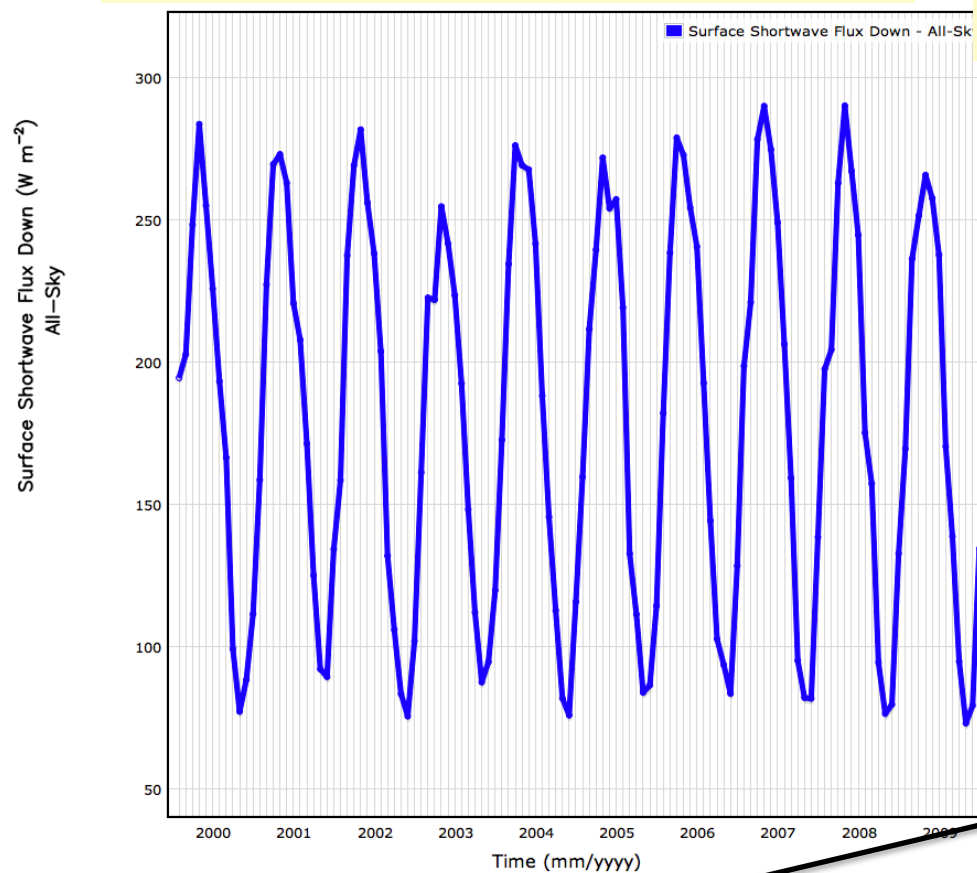
Histogram

Area Mean Time Series

Field Anomalies

Surface SWdown for site, 2000-2010

Surface SWdown for site,
deseasonalized



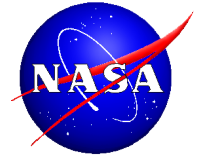
Selected Region: [36,284 ; 37,285]

Deseasonalize

Selected Region: [36,284 ; 37,285]

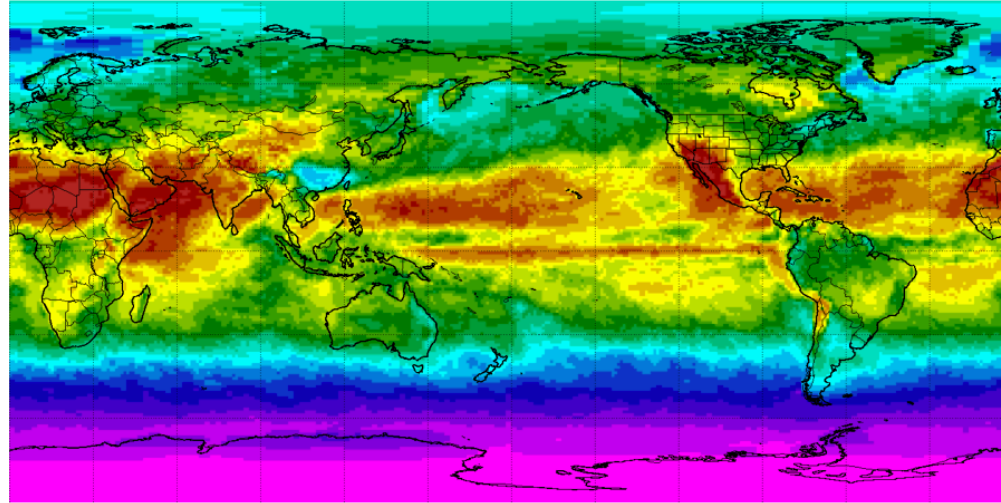
April 2000

April - 2000



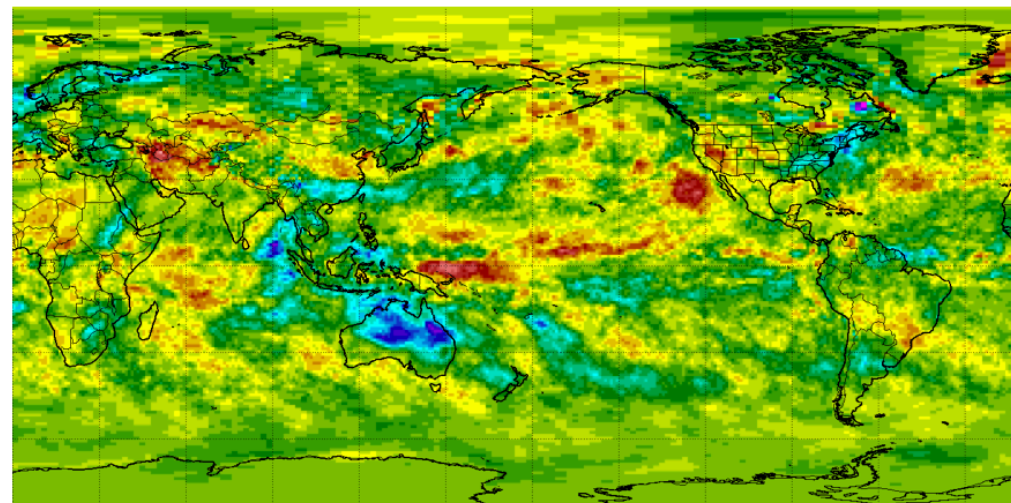
Surface SWdown

0
60
120
180
240
300



SWdown anomaly

-79.02
-56.99
-34.95
-12.92
9.11
31.14
53.18



Map Analysis Toolbar

Start Slide Show

Slower

Faster

Min/Max Values: 0 - 360

replot



Number of colors: 24

reset

Enable Google Earth

Save Data as ASCII File

Save Image as PNG

Histogram

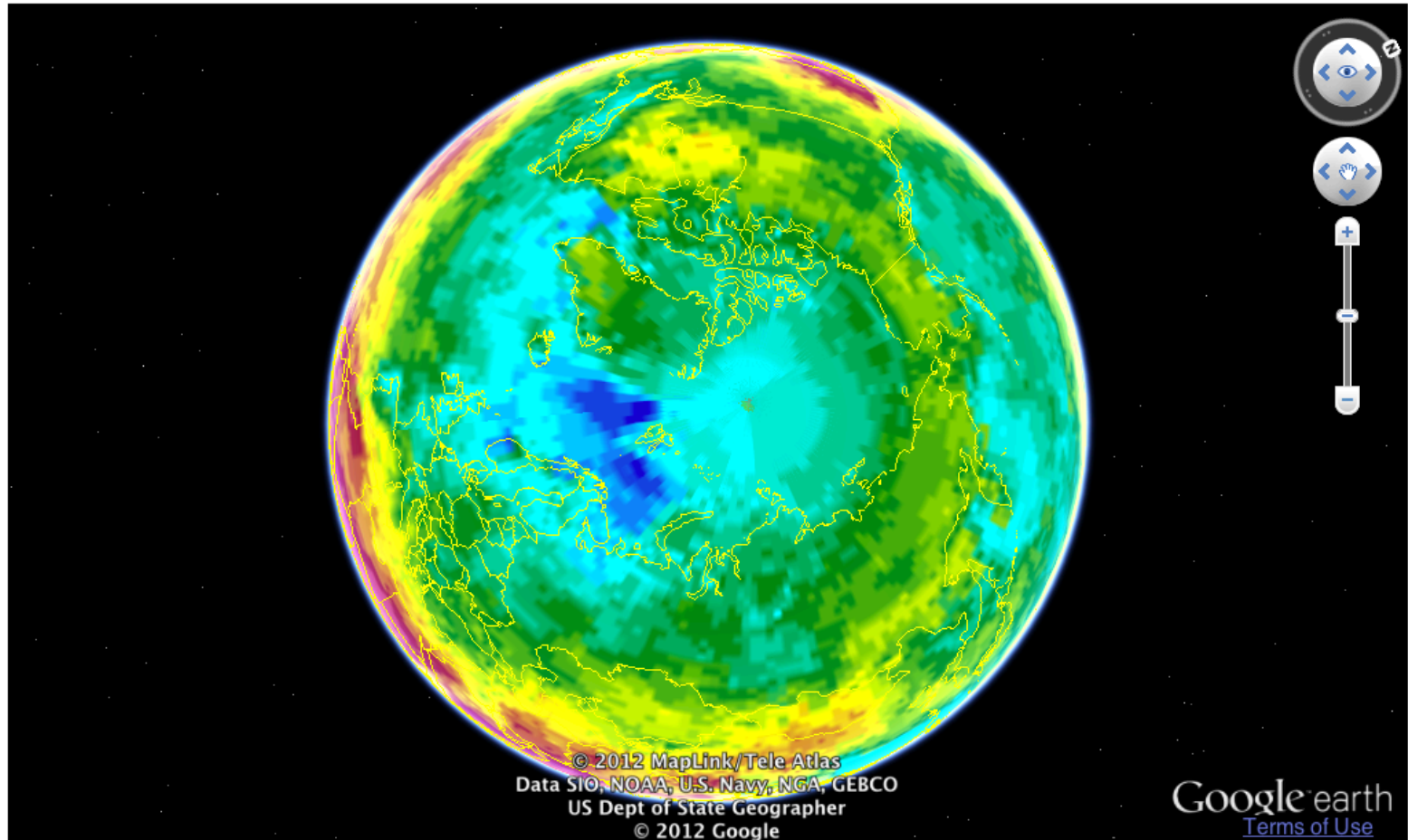
Area Mean Time Series

Field Anomalies

Google Earth Display

← April - 2000 →

0
60
120
180
240
300
360



Lat,Lon: (74.68, 32.87) Value = 89.670

Surface Shortwave Flux Down - All-Sky (W m^{-2})

Start Slide Show

Slower

Faster

Min/Max Values:

0

-

360

replot

Number of colors:

24

reset

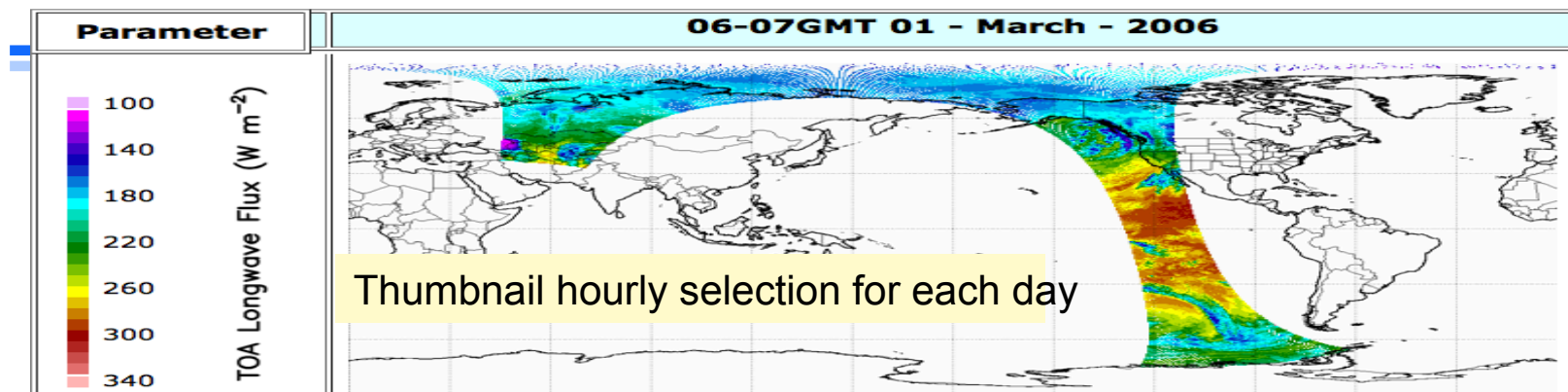


Disable Google Earth

Save Data as ASCII File

Save Image as PNG

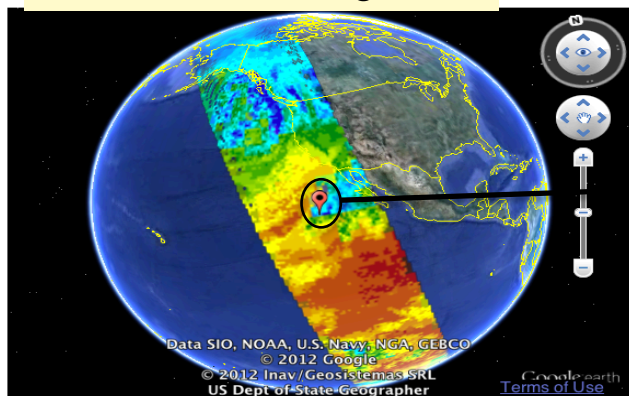
Level2 (20 km resolution) display, 6 GMT, March 2006



[Go Back Thumbnails](#)

SSF

Location on Google Earth

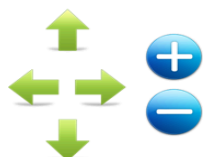


TOA Longwave Flux ($W\ m^{-2}$)

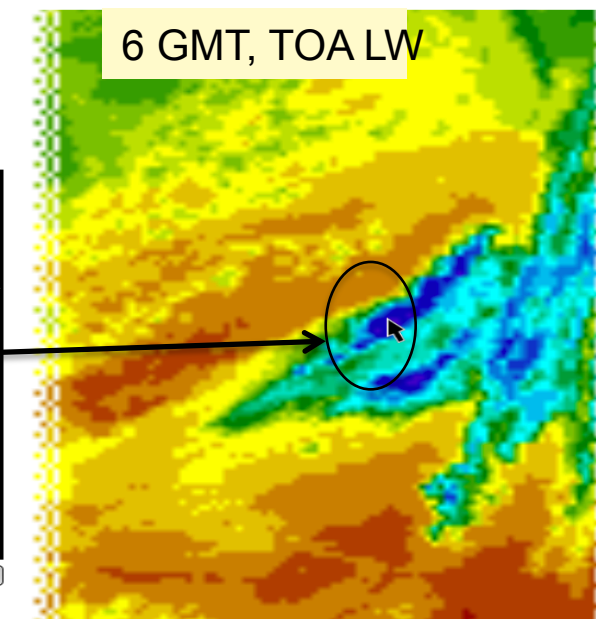
[Previous Hour](#) [Next Hour](#)

Pan/Zoom Control

Press z key and rotate mouse wheel can zoom in/out the images.



6 GMT, TOA LW



TOA Longwave Flux ($W\ m^{-2}$)

(lat, lon)=(26.68, -122.14) value=139.91185

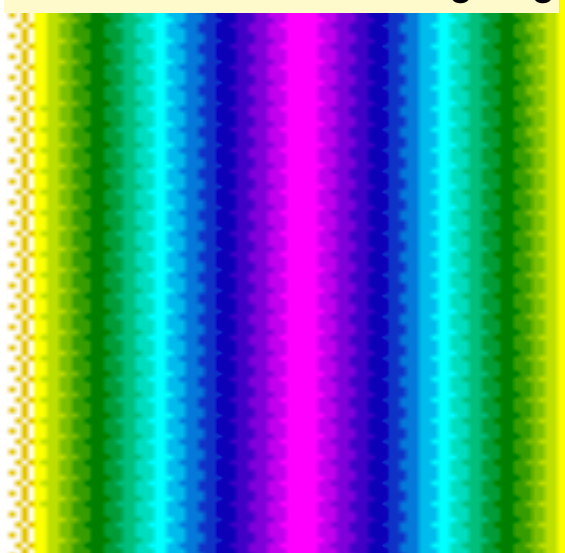


100.00 140.00 180.00 220.00 260.00 300.00 340

min: 100.00 max: 340.00 [replot](#)

number of colors: 24 [reset](#)

6 GMT, Satellite viewing angle



FOV Zenith Angle (deg)

(lat, lon)=(26.68, -122.14) value=14.662026

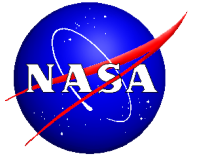


0.00 15.00 30.00 45.00 60.00 75.00 90

min: 0.00 max: 90.00 [replot](#)

number of colors: 24 [reset](#)

Product Stewardship



- Pre-Flight ATBDs for all CERES algorithms available on web
<http://ceres.larc.nasa.gov/atbd.php>
- Post PFM Launch algorithm updates maintained in journal articles and Data Quality Summaries
 - Science Team decision
 - Science community peer reviews articles
 - DQS distributed with data download
 - Algorithm updates posted in journal articles and referenced on CERES website

http://ceres.larc.nasa.gov/documents/publications/pdfs/CERES_Pubs_2010-1993.pdf

Example Application: Energy Monitoring with RETScreen Plus



Objective: Enable “users to monitor, analyze and report key energy performance data to facility operators, managers and senior decision-makers.”

Usage:

1. Determine & obtain building energy and meteorological information for any location in world
2. Use multivariate analysis to determine system performance as a function of meteorological variability
3. Monitoring building energy performance for system changes, target higher efficiency and reporting verification

RETScreen - NASA Langley Solar System

File Start Data Analytics Reporting

Resources naturelles Canada Natural Resources Canada

Canada

RETScreen Plus

Clean Energy Project Analysis Software

Project information [See project database](#)

Project name: NASA Langley Solar System

Project location: Hampton, VA USA

Prepared for: NASA

Prepared by: Paul Stackhouse

Show settings

RETScreen - Climate database

Country - region: United States of America

Province / State: Virginia

Climate data location: Newport News

Latitude: 37.1 °N

Longitude: -76.5 °E

Elevation: 16 m

Heating design temperature: -5.1 °C

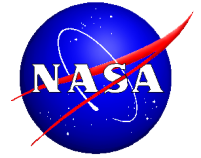
Cooling design temperature: 33.1 °C

Earth temperature amplitude: 18.7 °C

Source: NASA

Month	Air temperature °C	Relative humidity %	Daily solar radiation - horizontal kWh/m ² /d	Atmospheric pressure kPa	Wind speed m/s	Earth temperature °C	Heating degree-days 18 °C °C-d	Cooling degree-days 10 °C °C-d
January	4.2	66.9%	2.22	101.6	3.9	2.5	428	0
February	5.6	66.5%	2.97	101.6	4.0	4.5	347	0
March	9.3	64.3%	3.89	101.4	4.4	8.7	270	0
April	14.3	66.0%	5.04	101.2	4.3	14.9	111	129
May	19.0	71.8%	5.59	101.2	3.9	20.4	0	279
June	23.6	73.9%	5.89	101.2	3.7	24.6	0	408
July	26.2	74.4%	5.73	101.2	3.6	26.2	0	502
August	25.1	76.9%	5.29	101.3	3.5	24.9	0	468
September	21.7	77.3%	4.32	101.4	3.5	21.5	0	351
October	15.8	75.4%	3.36	101.6	3.4	15.7	68	180
November	11.1	71.0%	2.46	101.6	3.7	10.1	207	33
December	6.2	68.0%	1.95	101.7	3.8	4.4	366	0
Annual	15.2	71.1%	4.06	101.4	3.8	14.9	1,797	2,350
Source	Ground	Ground	Ground	NASA	Ground	NASA	Ground	Ground
Measured at	m	10	0					

Energy Monitoring and Targeting Case: NASA LaRC Badge and Pass Office



Use RETScreen
Plus & NASA
solar data to
assess solar
energy
production



Badge and Pass Office Solar Energy Project



Overview

Current Status

Weather Conditions

Installed in September 2010, this 39.5 KW ground-mounted solar energy system and will produce around 50,000 kilowatt-hours of electricity each year. The system consists of 168 photovoltaic modules mounted in two arrays located behind the Badge and Pass Office. This project demonstrates the performance of solar energy and the benefit of renewable energy being in our overall energy strategy.



*Example Kiosk
display output*

Energy Today



193
kWh

Total energy generated by the
system today

Energy Yesterday



206
kWh

Total energy generated by the
system yesterday

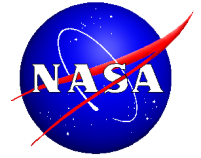
Lifetime Energy



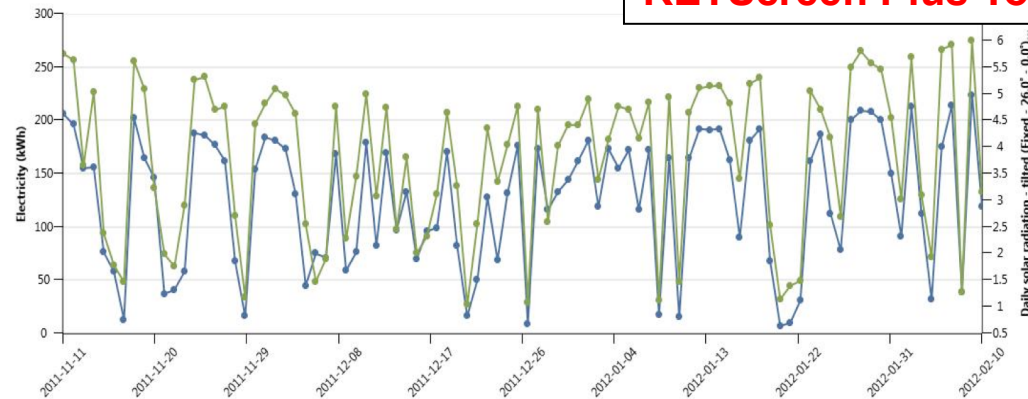
38,035
kWh

Total energy generated by the
system since installation

Monitoring and Targeting Case: NASA LaRC Badge and Pass Office

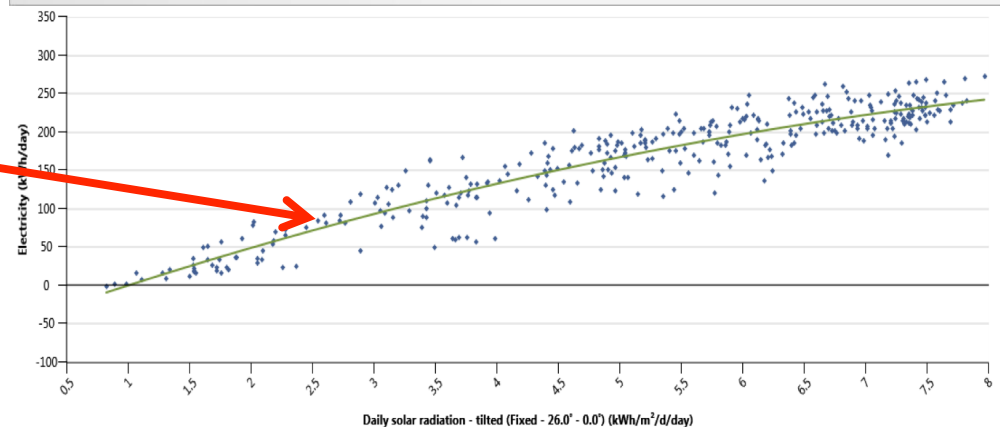


RETScreen Plus Tool

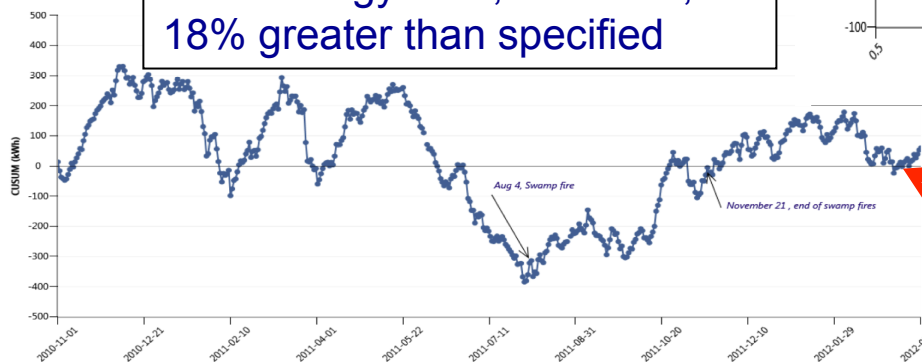


Step 1: LaRC based CERES FLASHFlux project surface solar flux (blue) vs. Solar Panel Electrical Output (green) gives excellent correlation.

Step 2: Regression relationship defines the system as a function of available solar energy

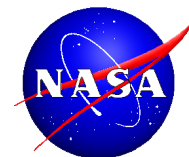


Total Energy = 59,000 kWhr,
18% greater than specified



Step 3: Cumulative differences in output relative to system function shows noise but performance steady.

CERES Conclusions



- Suomi NPP CERES FM-5 instrument working within expected specifications => validation & intercomparison continuing
- Calibration constant delivery and thus data product delivery goals on schedule.
- Level 3 & 4 (gridded and optimized TOA and surface radiative flux data products expected at end of 2013)
- CERES has new data subsetting capability that will help with browsing and downloading subsetted data sets.
 - Currently working with Aqua/Terra
 - Will be extended to NPP CERES upon when available consistent with other NPP data distribution requirements
- Applications with CERES are expanding taking advantage of the 10+ years of surface radiative parameters and extended near-real time data products.